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VISUAL DEPTH DISCRIMINATION

IN DAY-OLD CHICKS

by
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CHAPTER I

INTRODUCTION

A number of experiments have been reported which are concerned with assessing visual depth discrimination and the role of early visual experience in its formation (Shinkman, 1961). Recent experimentation has employed an apparatus known as the visual cliff and a wide variety of species for this purpose.

The visual cliff consists of a glass sheet resting on top of a large box, with a runway board extending across the middle of the glass. On one side of this runway board, a patterned surface is inserted directly underneath the glass. On the other side of the runway, the clear glass rests well above a patterned surface that covers the floor and inside walls of the box. The two halves of the apparatus, which are separated by the runway, are called the shallow side and the deep side, respectively, because of their optical properties. Animals to be tested for visual depth discrimination are placed on the runway. If they consistently leave the runway and descend to the glass on the shallow side, it may be concluded that their behavior is controlled by the visual depth cues arising from

the patterned surfaces, since the two halves of the apparatus are identical in every other respect.

Gibson and Walk (1960, 1961) used a visual cliff with red and white checkered patterns to test domestic chicks, hooded rats, and domestic kittens, and found that these species reliably chose the shallow side. This finding was the same for both light- and dark-reared animals, suggesting that the discriminative capacity is innate. In the case of chicks, the discrimination was obtainable with animals 24 hours old. Tallarico (1961) replicated the procedure using light-reared chicks that were 3 hours old, and found the same result.

Gibson and Walk also performed control experiments in which the underside of the glass sheet was covered with plain gray paper or with patterns on both sides of the runway, so that both sides appeared shallow. Rats tested under these conditions descended about equally often on the two sides. As an additional control, tests were made in which the patterns were arranged so that both sides of the runway were deep. Rats tested under this condition failed to leave the runway. Walk, Gibson, and Tighe (1957) found that rats raised in the dark reliably chose the shallow side of the visual cliff, as did normally reared control animals. Dark-reared animals in this experiment were allowed 20 minutes of light adaptation immediately before testing.

Nealey and Edwards (1960) replicated the Walk et. al. procedure, obtaining the same results, and tested two additional control groups. For animals in the first control group, the 20 minutes of light adaptation took place under individual translucent hoods, thus controlling for the possibility of very rapid learning during this period in the Walk et. al. study. Seventy-five per cent of the rats in this group chose the shallow side. Animals in the second control group were surgically blinded immediately before testing, as a control against non-visual cues. These animals did not discriminate between the shallow and deep sides.

Further experiments have been performed using the visual cliff, in which the aim was to isolate the visual cues responsible for the discrimination. Nealey (1961) studied the role of sharpness of focus in the depth discrimination of rats. He projected sharp and blurred patterns of equal size onto the two sides of a ground glass screen which replaced the glass sheet in the visual cliff. It was found that light-reared rats descended equally often on both sides. Nealey concluded that the behavior of rats on the visual cliff is not controlled by sharpness of focus.

Gibson and Walk (1960) investigated the importance of two principal visual cues to depth: relative motion parallax (rate of displacement on the retina of the images of the pattern elements as the animal moves along the runway) and size of the retinal

images of the pattern elements. Pattern image size was eliminated as a cue to depth by making the squares in the checkered pattern smaller on the shallow side, so that the pattern elements on the two sides gave rise to retinal images which were of equal size. With motion parallax presumably the only remaining differential depth cue, dark-reared chicks, aged 24 hours, and adult rats consistently chose the shallow side. In another experiment motion parallax differences were eliminated by placing the patterns directly under the glass on both sides of the runway, and retaining the difference in pattern sizes. In this way pattern size became the isolated cue; under this condition dark-reared chicks chose the two sides about equally often. From these two experiments it was concluded that motion parallax is an innate cue to depth and pattern size is not. The conclusion that motion parallax operates as an innate cue to depth for day-old chicks may not be accepted unequivocally, however, because these investigators failed to control several critical properties of the visual environment. In addition to motion parallax there remained several other optical differences between the shallow and deep stimulus configurations. First, the edges of the red and white squares comprising the shallow and deep patterns afforded the chicks differential accommodation and binocular convergence

cues. Second, the position of the runway board was such that lateral movement of the animal's head toward the shallow side would result in partial occlusion of the deep side pattern by the runway board, giving rise to interpositional visual depth cues. Third, the actual dimensions of the shallow side and the deep side were the same; hence the total retinal image sizes of the two sides differed considerably. The chicks might simply have chosen the apparently larger of the two surfaces. Fourth, the walls and especially the corners of the inside of the box on the deep side were visible from the runway, and probably served as perspective cues to the depth of the deep side. Fifth, there probably remained at least some light and shade differences between the shallow and deep sides, which could serve as visual depth cues. Any of these could have served singly or in combination as the basis for the discrimination.

The present experiment had three principal objectives. The first objective was to replicate the Gibson and Walk study, but with better control over the optical differences between the shallow and deep stimulus configurations. In order to gain such control, a modified version of the visual cliff was constructed. In this apparatus, shallow-deep differences were minimized with respect to apparent size of the patterns, apparent total

size of the two halves of the field, and perspective. Light and shade cues to depth were also eliminated because the shallow pattern and the deep pattern were translucent and illuminated from below, and the experimental space was rendered otherwise totally dark. Interpositional cues arising from the occlusion of the deep pattern by the runway board could be either admitted or excluded by an adjustment of the apparatus and were included as an experimental variable. Finally, accommodation, convergence, and binocular cues to depth were eliminated for certain experimental groups.

The second objective of the present study was to determine the properties of the stimulus field responsible for the shallow-deep discrimination, by systematic manipulation of some of the variables mentioned in the preceding paragraph.

The third objective was to find out if the apparently innate preference for the shallow side could be altered by exposing dark-reared animals to certain types of visual stimulation before testing them. In particular, animals in two of the experimental groups were each afforded two hours of exposure to a stimulus configuration resembling the deep side of the original Gibson and Walk visual cliff. It was conjectured that an association might form between somesthetic stimuli arising from a solid surface

of support (the glass floor) and certain of the depth cues arising from a patterned surface parallel to and about sixteen inches below the glass floor. Animals given this treatment would then be expected to choose the deep side instead of the shallow side when tested on the visual cliff.

CHAPTER II

METHOD

Subjects. Ss were 129 Leghorn chicks approximately 24 hours old when tested.

Apparatus. The apparatus (Fig. 1) was a modified version of the visual cliff (Gibson and Walk, 1960), consisting of a truncated cone resting on a square base. A hinged hemispherical top surmounted the cone. In the center of the top there was a covered, transparent circular window, 1.8 inches in diameter, through which the interior of the apparatus could be observed. At the top of the cone, 28.8 inches above the floor and level with the hinges connecting the hemisphere to the cone, there was a slot containing a removable sheet of plate glass which transected the cone at right angles to its principal axis, forming a circular platform 11.4 inches in diameter. At the bottom of the cone, 12.2 inches above the floor, a similar slot was cut to receive a larger sheet of glass which transected the cone in a circle 26.4 inches in diameter. The interior of the apparatus was painted flat black, and was illuminated by lights placed inside the square base.

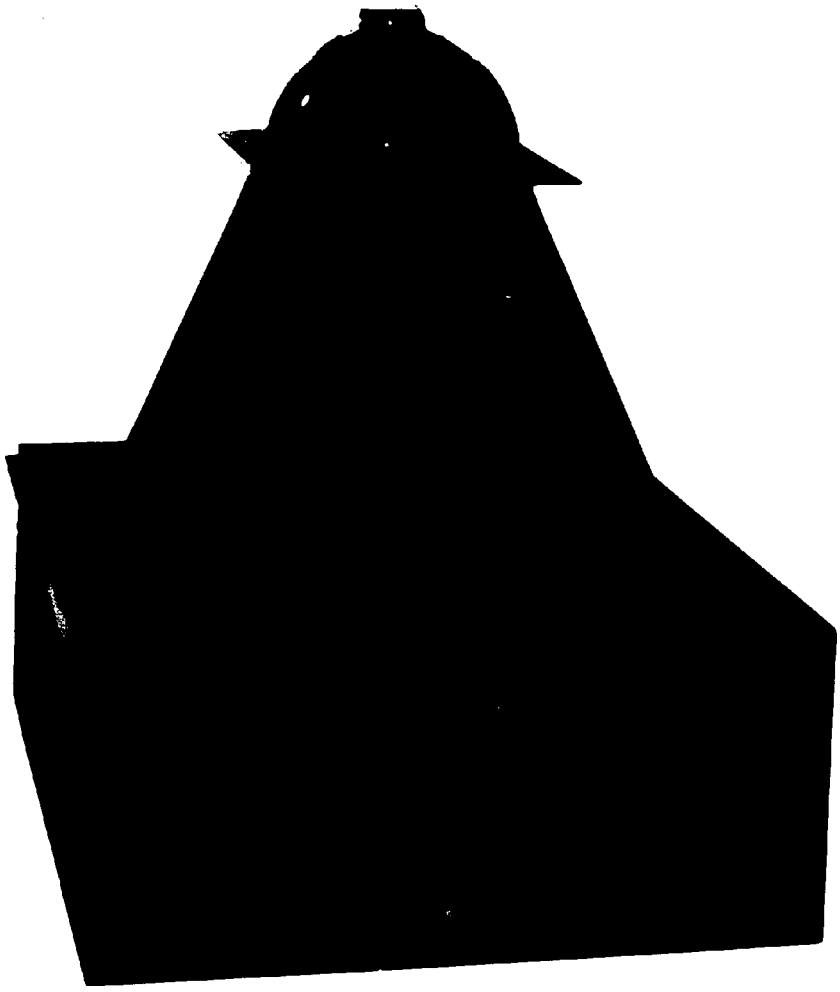


FIGURE 1. Side view of the modified visual cliff.

Three pairs of glass sheets constituted the three main stimulus conditions of the experiment, when inserted in the apparatus. In one condition (Fig. 2) the upper sheet of glass was transparent over its entire surface. The lower sheet contained a translucent red and white checkered pattern in the form of a square 18.5 inches on a side. The remaining area of the circle, outside this inscribed square, was painted flat black. This configuration was designated the extended field. In a second condition (Fig. 3) the upper sheet of glass was prepared in a similarly inscribed square pattern, 8.0 inches on a side and surrounded by flat black, and the lower sheet was transparent. This condition was designated the normal field. The configuration for the third condition (Fig. 4) resembled the original visual cliff of Gibson and Walk. In this condition the right side of the upper sheet was prepared in a rectangular checkered pattern 3.5 by 8.0 inches, surrounded on the three outer sides by flat black, and the entire left side of the upper sheet was transparent. The left side of the lower sheet contained a rectangular pattern 8.1 by 18.5 inches, surrounded by flat black, and the entire right side of the lower sheet was transparent. A cardboard trapezoid, painted flat black, extended nearly perpendicularly between the two glass sheets. The top of the trapezoid coincided with the left edge of the pattern on the upper sheet of glass, the bottom of the trapezoid

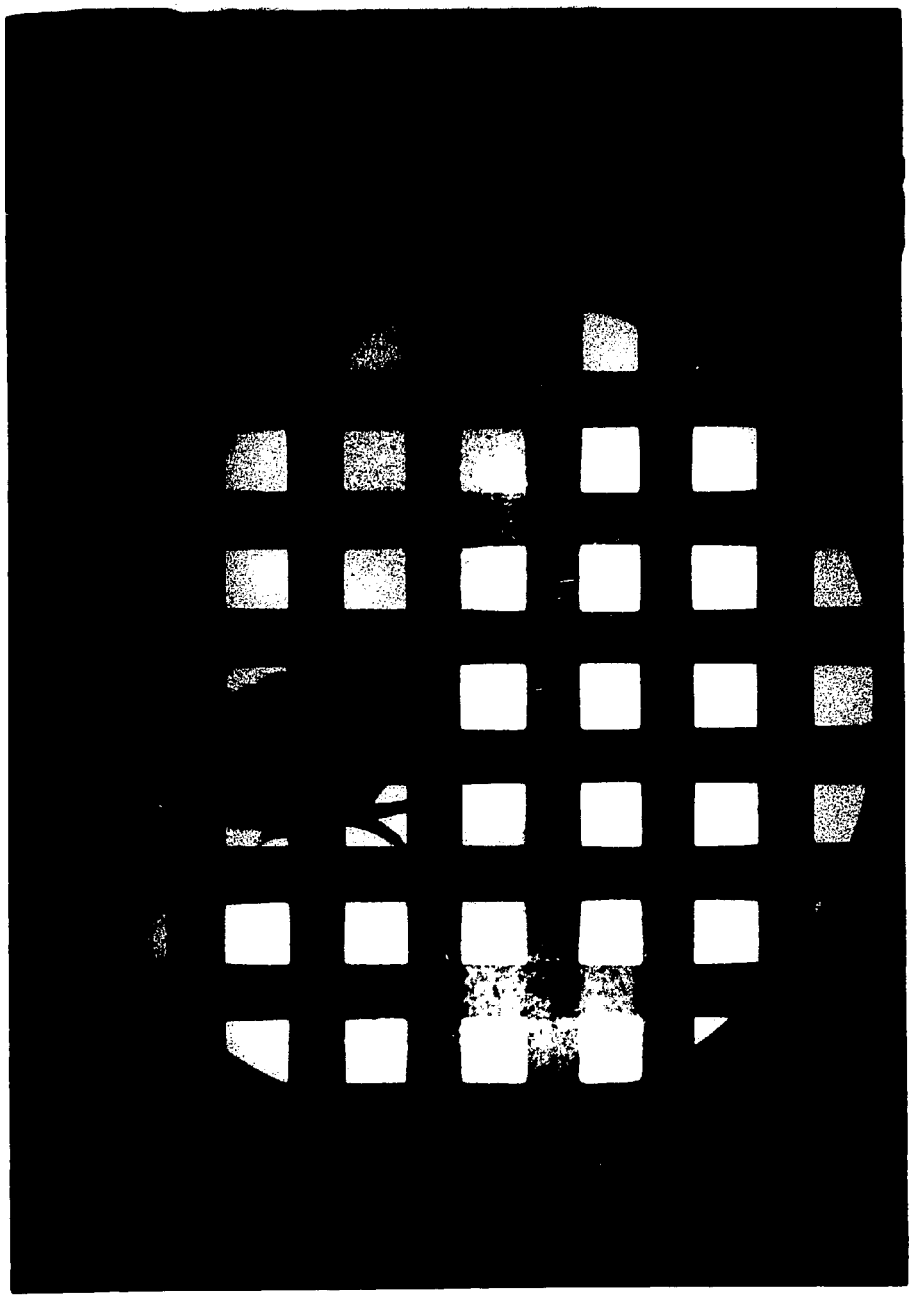


FIGURE 2. Top view of the modified visual cliff, showing the extended field configuration. The border, which was actually square, appears circular because of the height from which the photograph was taken.

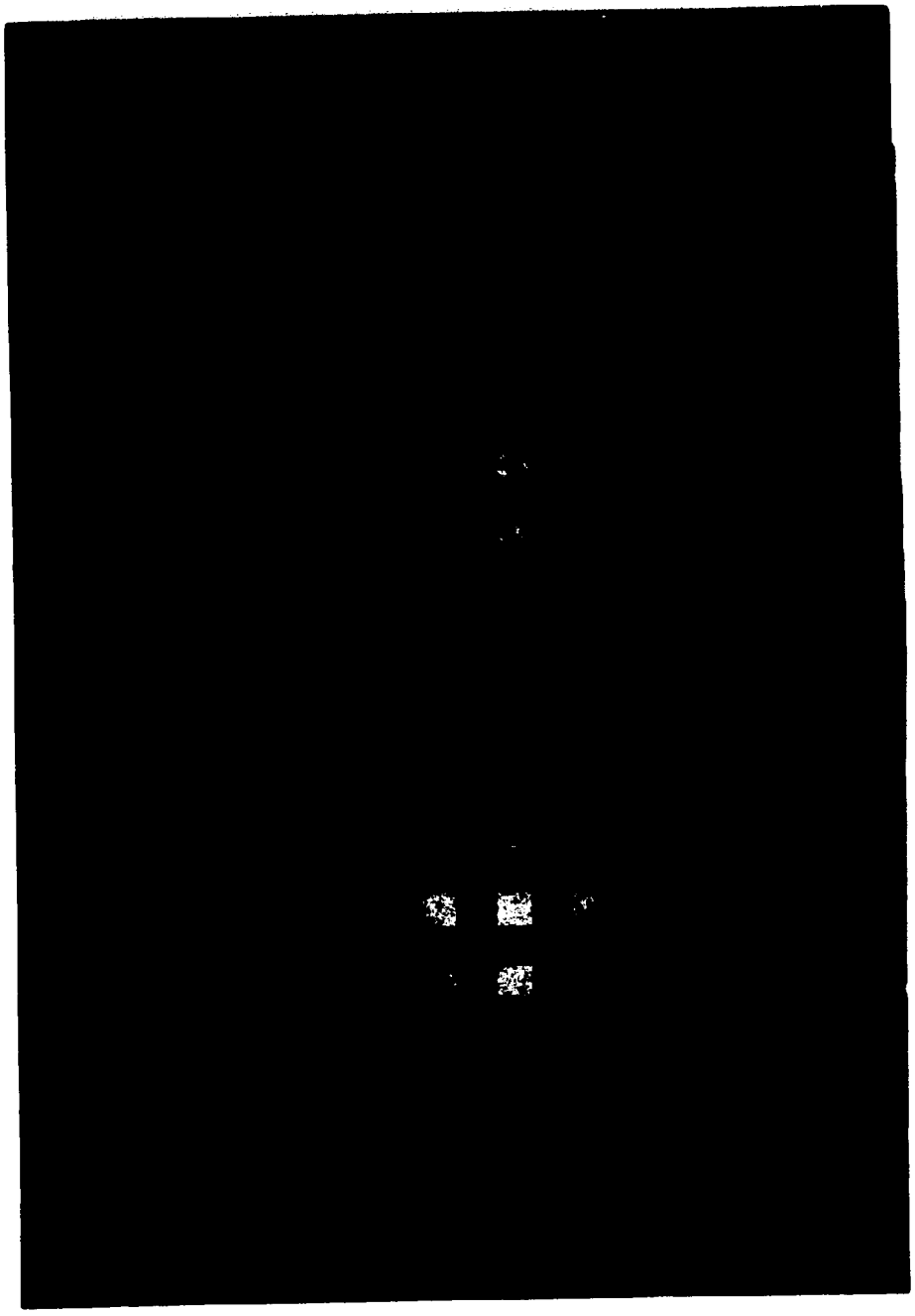


FIGURE 3. Top view of the modified visual cliff, showing the normal field configuration.

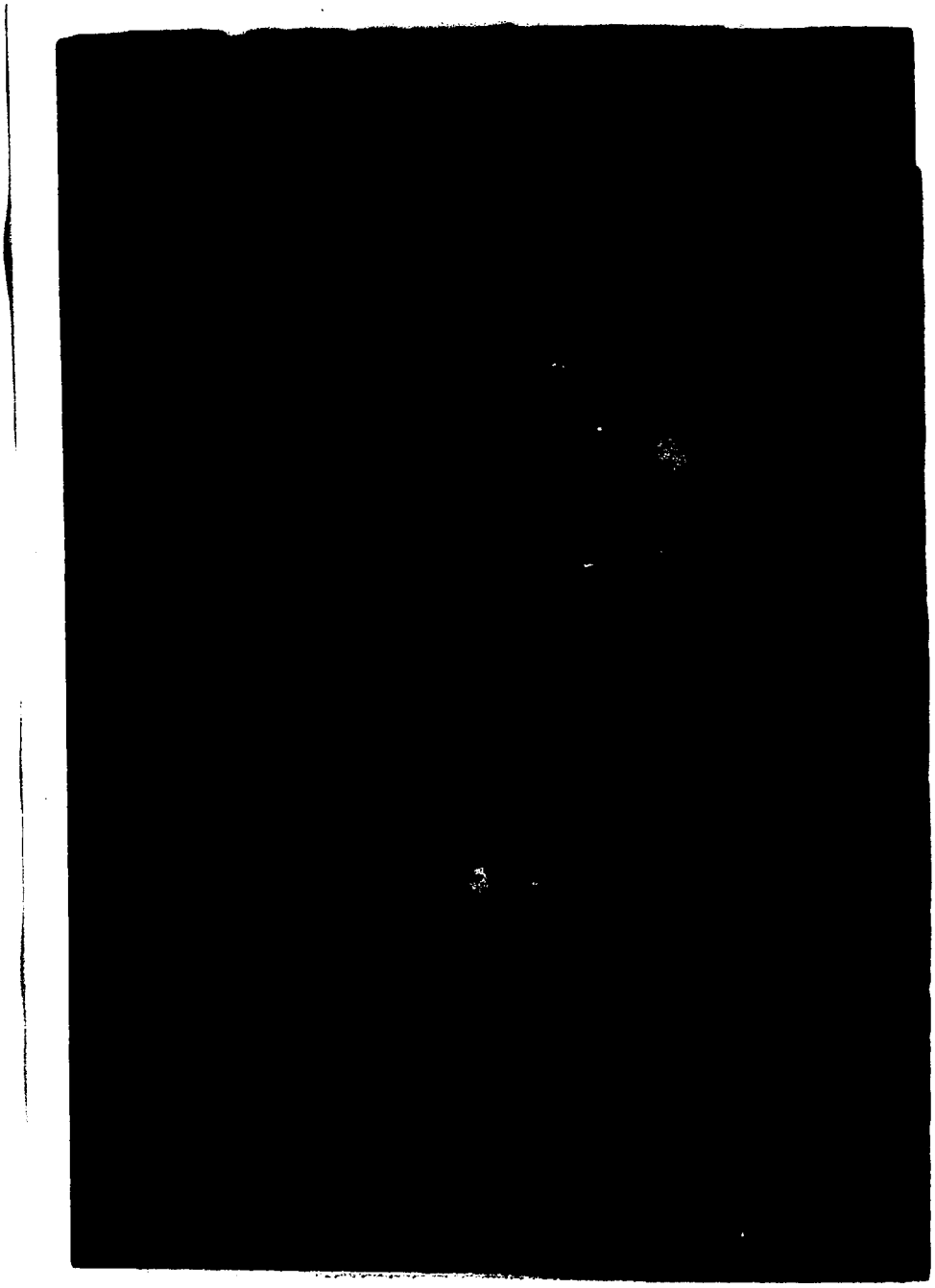


FIGURE 4. Top view of the modified visual cliff, showing the test field configuration. The border on the deep side, which was actually square, appears circular because of the height from which the photograph was taken.

coincided with the right edge of the pattern on the lower sheet, and the sides of the trapezoid were flush with the cone. This last condition was designated the test field. The two sides of the test field were designated the shallow side and the deep side, and the band in the center, directly above the cardboard trapezoid, was designated the runway area. A small board, .5 x 2.4 x 9.9 inches and painted flat black, was placed in the runway area for certain of the experimental groups. This board served the same function as the runway board in the original visual cliff (Gibson and Walk, 1960).

Two 150-watt "Soft-White" bulbs were mounted inside the square base, one on each side. Each bulb was connected in series with an autotransformer which was adjusted so that the luminance was the same on both sides of the test field. The level of illumination was 6.0 foot-lamberts in the extended field, 7.1 foot-lamberts in the normal field, 3.8 foot-lamberts on the deep side of the test field, and 3.6 foot-lamberts on the shallow side of the test field, as measured with a Macbeth illuminometer. Both sides of the test field were kept between 95 and 96 degrees Fahrenheit.

In both the normal field and the extended field, the translucent red and white checkered pattern consisted of 256 squares (sixteen rows of sixteen each) The squares in the normal field

pattern were .50 inches on a side, and the squares in the extended field pattern were 1.16 inches on a side. On each side of the test field there were 112 squares (seven rows of sixteen each); the squares on the shallow side were .50 inches on a side, and the squares on the deep side were 1.16 inches on a side. This set of pattern dimensions was chosen to have the following property: the apex of the cone would have been at a point 41.4 inches above the floor (12.6 inches above the upper sheet of glass) if the cone had not been truncated. To a stationary observer at this imaginary apex, the three stimulus configurations (extended field, normal field, and test field) were optically indistinguishable in terms of perspective, size of the squares comprising the patterns, and total size of the patterns (except for the test field runway area).

Procedure. The basic testing procedure was the same for animals in all the experimental groups. The animal to be tested was brought out of total darkness and placed at one end of the runway area or runway board (depending on the group it belonged to), facing along the runway. The hemispherical top was then closed, the transparent window in the top was uncovered, and the behavior of the animal was observed through the window. During this observation period the experimental room was completely dark, so that no

light entered the apparatus from outside. A response was said to occur the first time the animal moved completely out of the runway area or, if it was on the runway board, the first time it moved off the board and placed both feet flat on one side of the test field. The latency of the response was measured from the time the animal was placed on the runway. If the animal failed to respond within thirty minutes, the trial was terminated. After the response occurred, the position of the animal (shallow or deep side of the runway) was recorded continuously during a ten-minute observation period. The hemisphere was then lifted, the animal was picked up and placed at the opposite end of the runway, facing along the runway, and the entire procedure was repeated. Thus each animal was given two complete trials with the shallow side once on the left and once on the right The order of the trials was counterbalanced over animals.

At the beginning of the experiment, a few chicks were given only one trial each, and the observation period ended when the first response occurred. Later the two-trial procedure and then the extended observation period were introduced. Starting with the 34th experimental animal, all chicks were tested using the procedure described in the preceding paragraph.

There were twelve experimental groups, differing with

respect to the visual stimulation to which the animals were exposed prior to testing, and also with respect to certain parameters of the testing situation. Three types of prior visual stimulation were used. In one type, each chick was hatched and raised in total darkness except for two hours spent in the extended field immediately prior to being tested. Groups given this treatment comprised the extended field series. A second series of groups was given identical treatment except that the two hours immediately prior to testing were spent in the normal field; groups given this treatment comprised the normal field series. In the third type of prior visual stimulation, each chick was completely dark-reared except for a ten-minute period spent in a translucent white plastic bag, immediately prior to testing. This procedure allowed initial light adaptation to occur, without exposing the chick to any patterned visual stimulation. Groups given this treatment comprised the dark-reared series.

Three parametric variables were introduced in the testing situation, each one having two values. First, the runway board was present in the test field for some groups, and for other groups it was not. Second, animals in some groups were allowed binocular vision, while animals in other groups were reduced to monocular vision by a patch of black tape over one eye. Half the monocular

animals retained vision in the left eye, and half in the right eye. The order of the trials was counterbalanced within left-eyed animals and also within right-eyed animals. Third, animals in some of the dark-reared groups were given a topical application of two drops of d-tubocurarine chloride in each eye (or in the unpatched eye, in the case of monocular animals) immediately after the light adaptation period. Exactly five minutes then elapsed before testing. For other dark-reared groups, this treatment was omitted. Selected combinations of these variables with the type of prior visual stimulation were used to constitute ten experimental groups.

The attitude of the apparatus in the experimental room was constant throughout the experiment, so that differences not associated with the stimulus patterns might have existed between the two sides of the test field (for example slight imperfections in the interior of the hemisphere, or possible auditory stimuli) In order to determine whether any of these differences were controlling side preference, two control groups were employed. No drugs were administered to chicks in the control groups, and binocular vision was allowed. For one group the test field was constructed by placing the runway board in the center of the extended field, so that both sides were deep. For the other group the test field was constructed by placing the runway board in the center of the normal field, so that both sides

were shallow. For the purpose of labelling the responses made by animals in these two groups the side of the apparatus which normally contained the shallow side of the test field was designated the shallow side, and the other side was designated the deep side.

CHAPTER III

RESULTS AND DISCUSSION

The two primary dependent variables were proportion of responses made to the shallow side, and average proportion of time spent on the shallow side during the observation period. Table 1 gives these proportions for the two control groups, Table 2 shows the proportions for the extended field and normal field series, and Table 3 shows the proportions for the dark-reared series The remaining dependent measures, response latency and number of times the runway was crossed, failed to relate systematically to the experimental variables

The data strongly support the conclusion that day-old chicks exhibit visual depth discrimination in the absence of prior patterned visual stimulation This result is in accord with the previous research described in the Introduction. The data of Table 1 establish that the discrimination was visual, since animals in the two control groups failed to discriminate when afforded the same non-visual cues as the experimental animals.

Table 1. Visual cliff behavior of dark-reared chicks from two control groups. Proportion of responses and time spent on the "shallow"side. The number of trials on which each proportion is based appears in parentheses.

		Proportion of responses to the side which was shallow for the experimental groups.	Proportion of time spent on the side which was shallow for the experimental groups.
Condition	Both sides shallow	.50 (12)	.46 (12)
	Both sides deep	.52 (23)	.52 (23)

Five additional major conclusions can be drawn from the data in Tables 2 and 3. First, comparison of data for the extended field group (Table 2) with that of the dark-reared group (Table 3) shows that the only effect of extended field training before testing is to reduce somewhat the extent to which chicks choose the shallow side. The training does not contravene the animals' innate avoidance of the deep side, but simply reduces it. In the absence of a runway board, the proportions of responses to and time spent on the shallow side

Table 2. Visual cliff behavior of dark-reared chicks following exposure to an extended or a normal field. In each cell the upper number is the proportion of responses made to the shallow side, and the lower number is the average proportion of time spent on the shallow side. The number of trials on which each proportion is based appears in parentheses.

		Prior visual exposure	
		extended field	normal field
Runway board	absent	.70 (47) .70 (35)	.65 (23) .63 (22)
	present	.75 (8) .61 (8)	.83 (6) .89 (6)

fall from .80 and .92, respectively, to .70 and .70, as a result of extended field pre-exposure. This effect is probably due to adaptation and familiarization with the apparatus, occurring during the extended field exposure period. The normal field series was conceived as a control in case extended field exposure affected the discrimination. As it turned out, the data from the normal field series simply reflect the same adaptation effect as the data from the extended field series.

Second, the data in Tables 2 and 3 indicate that the extent to which chicks discriminate is typically increased when the runway board is introduced in the test field. Since the runway board affords interpositional cues to the depth of the deep side, it is probable that interposition plays a part in the depth discrimination of day-old chicks, both light- and dark-reared.

Third, the data in Table 3 show that the extent of the discrimination decreases when the experimental animals are reduced to monocular vision, suggesting that binocular cues have some importance. In the present experiment the principal binocular cue was convergence.

Fourth, the topical application of d-tubocurarine chloride on the cornea five minutes before testing dramatically reduces the extent to which the animals discriminate when the runway board is absent from the test field. This drug is a curare derivative and is known to function as a blocking agent in the transmission of impulses from motor neurons to striated muscle fibres (Sollmann, 1957). The muscles in the avian ciliary body and iris, controlling the accommodation of the lens and the curvature of the cornea, are striated (Thomson, 1923; Van Tyne and Berger, 1959); birds and reptiles differ in this respect from other vertebrates. Consequently it is likely that topically applied

Table 3. Visual cliff behavior of dark-reared chicks. In each cell the upper number is the proportion of responses made to the shallow side, and the lower number is the average proportion of time spent on the shallow side. The number of trials on which each proportion is based appears in parentheses.

		D-tubocurarine chloride			
		Not administered		Administered	
		Runway board		Runway board	
		absent	present	absent	present
Vision	binocular	.80 (25) .92 (4)	.79 (14) .84 (14)	.64 (14) .69 (14)	.78 (9) .90 (9)
	monocular	.88 (8) .74 (8)		.54 (13) .68 (13)	

curare reduces or eliminates the chick's ability to bring stimuli at different distances into focus. Therefore, the reduced discrimination which characterizes the curarized animals in the absence of the runway board suggests the importance of accommodation as an innate depth cue. It is unlikely that the curare destroyed or seriously

impaired the animals' vision, since curarized chicks discriminated well when afforded interpositional depth cues by the presence of the runway board.

Fifth, it will be noticed that the lowest level of discrimination occurred among those animals for which the number of visual depth cues was reduced as far as possible within the limits set by the construction of the apparatus (that is, the animals that were curarized and reduced to monocular vision, and for which the runway board was absent). For these animals, only the following optical differences existed between the shallow and deep sides: relative motion parallax, whatever focussing capacity remained after the curare took effect, and whatever marginal cues were afforded by imperfections in the apparatus. These marginal cues were of two kinds: first, the reflectance of the flat black paint covering the inside of the cone was not zero, so that there were at least some perspective cues present on the deep side, afforded by the inside wall of the cone. Second, although the shallow and deep patterns were optically indistinguishable at the imaginary apex of the cone in terms of perspective, apparent size of the pattern elements, and apparent total size of the patterns in the two halves of the apparatus, the animal on the runway was not situated at this imaginary apex, and was not

stationary. Hence the indistinguishable character of the two sides with respect to these cues represents an ideal which was not met. However, in view of the extent to which the cues arising from apparatus imperfections were minimized, it seems likely that motion parallax was the most important remaining cue. The fact that these animals discriminated poorly casts doubt, therefore, on the importance of motion parallax as an innate visual depth cue.

The above conlusions combine to support the general statement that accommodation, binocular convergence, and interposition contribute disjunctively to the visual depth discrimination of dark-reared chicks. Removing any two of these cues from the test field reduces the extent to which chicks discriminate, and eliminating all three cues reduces the extent of the discrimination still further.

CHAPTER IV

SUMMARY

Gibson and Walk (1960), Walk, Gibson, and Tighe (1957), and others have investigated visual depth discrimination in animals using an apparatus known as the visual cliff. The visual cliff consists of a runway board placed on a glass sheet, with patterned surfaces underneath and parallel with the glass. On one side of the runway the patterned surface is directly below the glass, and on the other side the patterned surface is about two feet below the level of the glass. The two sides of the apparatus are called the shallow side and the deep side, respectively. Animals are tested by placing them on the runway and observing whether they descend to the glass on the shallow side or on the deep side. Consistent choice of the shallow side is interpreted as evidence of visual depth discrimination.

Following a series of experiments using the visual cliff to test dark-reared animals, these authors concluded that kittens, rats, and day-old chicks discriminate depth innately. It was further concluded that motion parallax differences between the shallow and deep sides played an important role in the discrimination.

The present experiment had three principal objectives. The first objective was to replicate the Gibson and Walk procedure with improved control over the visual depth cues available to the animal. The second objective was to explore in greater detail the relative importance of the visual cues serving as the basis for the discrimination. The third objective was to investigate the possibility of contravening the animals' innate avoidance of the deep side by exposing them, during the two hours immediately prior to testing, to a stimulus configuration resembling the deep side of the visual cliff.

To accomplish these objectives, a modified version of the visual cliff was constructed. Dark-reared animals, and also animals given prior exposure to stimulus fields resembling the shallow side alone and the deep side alone, were tested in this apparatus under a variety of conditions. Some animals had binocular vision and others were reduced to monocular vision. For some animals the runway board, which afforded interpositional cues to the depth of the deep side, was removed from the apparatus during testing, and for others it remained. Finally, some animals received a topical application of d-tubocurarine chloride on the cornea five minutes before testing, and others did not. This treatment was presumed to eliminate visual depth cues arising

from differential accommodation, since the relevant muscles in the chick's eye are striated and this drug immobilizes striated muscle. Testing conditions for the several experimental groups were generated by combining the variables described above. In addition, two dark-reared control groups were tested: one for which both sides of the apparatus were shallow, and one for which both sides of the apparatus were deep.

An analysis of the proportion of responses to and time spent on the shallow side of a visual cliff by 129 Leghorn chicks supported the following principal conclusions:

1. Day-old chicks exhibit visual depth discrimination in the absence of prior patterned visual stimulation.

2. Under the conditions of the present experiment, it is not possible to contravene the animals' innate avoidance of the deep side of the visual cliff.

3. The extent to which chicks discriminate is reduced under any of the following conditions:

   a. The animal has an opportunity to adapt to the test apparatus.

   b. Binocular depth cues are eliminated from the testing situation.

   c. Interpositional depth cues are eliminated from the testing situation.

d. Depth cues arising from differential accommodation are eliminated from the testing situation.

4. The extent to which chicks discriminate is considerably reduced when all of the above visual depth cues are simultaneously eliminated from the testing situation, leaving motion parallax as the principal remaining cue.

The above conclusions combine to support the general statement that visual depth cues operate disjunctively as determinants of visual depth discrimination in day-old chicks

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